Web-based Physician Order Entry: An Open Source Solution with Broad Physician Involvement.

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Abstract

Computerized physician order entry (CPOE) is a disruptive technology but holds great promise for reducing medical errors, improving workflow and in the long run, producing cost-savings. However, many studies have reported significant physician resistance to implementing CPOE. In this manuscript we present a two-prong strategy for quick implementation of CPOE: 1) a web-based deployment tool using an open source, secure environment that allows rapid development and deployment of content, and 2) the development of a large set of disease specific order sets and knowledge bases based on established vocabulary standards such as LOINC and SNOMED CT by teams of multidisciplinary content experts at the departmental level. The order sets can be viewed, edited and signed through a standard browser interface. This paper presents the conceptual framework and implementation requirements for such an endeavor.

Introduction

Computerized Physician order entry (CPOE) has been identified as a key strategy to reduce medical errors [1]. Further, structured order sets offer the benefits of reduced errors of omission, improved documentation and cost savings [2,3,4]. However, multiple studies have shown that CPOE can be wasteful of physician time and a source of discord among the medical staff [5,6]. Reviews of implementation strategies have commented that the development of structured order sets by clinicians within the organization is an important contributor to CPOE success [4,7]. Order entry projects are typically lengthy, often requiring major enterprise resources for periods of three to ten years [7]. The strategic problem then, is how to get the clinical care community to sustain interest in the development and use of CPOE when the final implementation may be years away.

The University of Nebraska Medical Center is participating in a multicenter grant from the National Institutes of Standards and Technology Advanced Technology Grant (NIST-ATP)[8] to develop new methods and technologies to implement computerized guideline and knowledge base support for order entry systems that will interrelate with existing electronic medical records. The NIST-ATP project is developing a significant body of structured clinical data for deployment. However, the output of this project will not be available for clinical implementation for several years. Therefore, our challenge is how to generate substantial involvement by physicians and other health care professionals to develop order sets and knowledge bases that will not immediately be fully integrated into our electronic medical record (in this case, IDX CareCast™).

To overcome this challenge we developed a web-based physician order entry platform. This approach allows the rapid prototyping, development and dissemination of structured order sets, checklists, care plans and routing of documents through a secure intranet to our clinicians for immediate use and feedback.

Project Requirements

At its inception we delineated the overarching requirements of the web-based CPOE project. They included a robust relational database that also supported object-oriented data structures (a 'hybrid' data structure). The database needed to support order indexing, history of patient orders and data mining. We wanted a stable developmental environment and the ability to support rapid development and implementation. The system must be accessible through a standard browser interface that allows flexibility and an intuitive user-interface. Further, it needed to have strong security features that were HIPAA compliant. Additional requirements included the ability to handle multiple simultaneous users, to allow role delineation and role-defined views of the data as well as electronic signature. It needed to utilize IP and terminal ID functions for printing and routing.

Web-based CPOE functionality

1) HIPAA compliant security: Security is key to any clinical data system. This system is launched within the IDX Carecast electronic medical record and

passes encrypted user authorization and context specific information to the browser session.

2) Standards-based medical vocabulary: Data standards are critical to interoperability. We have built this system based on SNOMED CT and LOINC vocabulary.

3) Routing of orders: Order output must be routed to printers via IP or terminal ID functions. Additionally, orders can be routed to specific users.

4) Role Specificity: Health care professionals (physicians, pharmacists, nurses, etc.) benefit from views of the data customized to their needs and access clearance.

5) Specialty Specification: The system needs to guide the user to the most relevant order sets and care plans for their individual specialty. As users become more familiar with the order sets they can establish their own preferences that are stored in the database.

6) Disease Specific Guidelines: Order sets and clinical progression are classified by disease-state according to UNMC problem list vocabulary based on SNOMED RT[11]. The clinician may choose his or her disease-states to include in their list.

7) Individual Secure Sign-on: This feature further defines access beyond role and allows for customized views of datasets. For example, orthopedic surgeons see CPOE tailored to their specialty. This information also allows electronic signatures and document routing to others such as nurses, physical therapists and pharmacists.

8) Order Sets and Nested Order Sets: This process codifies orders into data elements that fit into a structured hierarchy, which we call subsets (admission orders, laboratory orders, pharmacy orders, etc). Nested order sets represent reusable, complex orders such as anticoagulation that may be used in many different scenarios by many different clinicians. An order set with an expanded nested order set is shown in figure 1. The nested order set includes not only the medications, but the appropriate lab work and nursing guidelines.

9) Checklists and Care Plans: In a specific episode of care, workflow can be as important as order sets. Checklists assign responsibility for actions to members of the health care team and allow for confirmation and routing. For instance, during an episode of care (such as a total hip replacement), a care plan contains pre-operative orders, post-operative orders, orders by day post-op and discharge orders.

10) Pharmacy Sets: Medication administration can represent a very complex set of orders, which may cross many diverse order sets. Data features must include class, trade and generic names, route of administration, dosage, formulary availability and in many cases calculations based on weight, age, renal function, etc. Allergy checking and dosing algorithms can be added if essential data is passed from the hospital information system.

11) Preferences: Default orders can be set with preferences. Based on the individual rules, several individual orders can be accepted while some orders are mutually exclusive. For instance, both heparin and warfarin may be given together or separately while certain diets are mutually exclusive. Preferences can dramatically accelerate CPOE while reducing orders of omission and conflict resolution.

12) Edit/review mode: The health care provider sees the complete list of orders selected for review prior to signature. An electronic signature is applied to the orders at the end of the session.

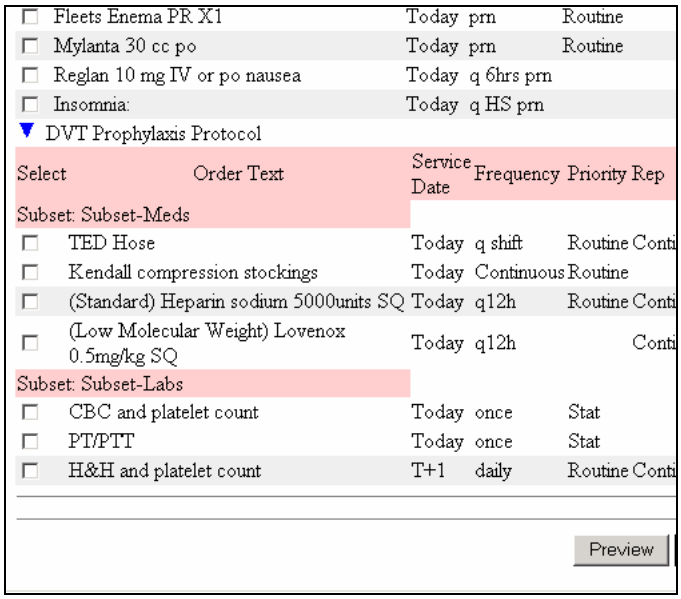

Figure 1:This figure demonstrates part of an order set. Note the dark arrow; this represents a nested order set. The down position gives the expanded view of the nested order set. It allows multiple choices for deep vein thrombosis prophylaxis and appropriate associated orders.

13) Accessibly to portable computing: While the ideal input device for CPOE has not been established, secure wireless communication is essential to

widespread implementation and acceptance. By design, this system will work through any secure browser interface from tablets to PCs.

14) Persistence: Order documents must be reproducible in their original electronic format after printing.

Technologic Considerations

We chose to develop our project using open source solutions. Red Hat Linux version 7.2, which was factory-installed on a Dell 2650 Power Edge server, was selected as our operating system. Zope was chosen as the application server (www.zope.com). It is a robust open source solution. The Zope toolbox provides an environment that supports simplified design, development and testing. It is programmable through a standard web-browser. It utilizes the Python (www.python.org) programming language which supports object-oriented programming; and has its own mark-up language, data-text markup language (DTML) and template authoring language (TAL). Complex document printing is performed through LaTeX scripting.

MySQL (http://www.mysql.com/) was chosen as the database engine. MySQL is an OBDC compliant SQL database that is open source, has proven stability and has been used in multiple large medical database applications[9,10] and can connect to decision-support tools.

The physician order entry platform requires the ability to build orders in a flexible intelligent manner. To facilitate this process we have elected to employ a hybrid database, part relational, part object-oriented. This can be thought of in the following fashion. The relational database serves as a folder with an identification tab. The object-oriented data is the data within the folder. Python supports a feature referred to as "pickling". Pickling an object preserves the object's internal structure while encoding it as a single string.

To handle objects when they are not in the database, we use Zope's External Methods to leverage Python Classes which have the ability to store the object framework and the methods to interact with the object. Thus when there are new requirements we can create new objects without modifying the existing database structures.

Security features include the ability to fire a secure web browser through a custom interface within the IDX Carecast™ electronic medical record system. This system resides within the UNMC/NHS firewall and uses SSL encryption. Access outside the firewall is available to authorized users through a Cisco VPN client using triple DES encryption.

Implementation Strategy

Computerized Physician Order Entry promises to reduce medical errors and improve workflow; however, many factors can affect its implementation success. Recently, Cedars-Sinai has "pulled the plug" on their CPOE system. As delineated in a recent article by Bill Briggs[3], CPOE faces three hurdles; the cost of the CPOE, its integration with other order entry systems and cultural, especially physician acceptance. Various CPOE projects have been shown to increase physician work time by 30 to 60 minutes, especially during the introduction of the project. Ash[5] noted that surgical specialties were potentially better targets for early implementation because of their rather well delineated diseases and problems.

While awaiting the end-to-end solution promised by the NIST-ATP grant[8] we elected to develop a two-pronged strategy: 1) Develop a web-based system for immediate implementation of CPOE on a user-by-user basis (department by department). 2) Build a large collection of structured order sets based on episodes of care such as disease states and care plans. A core multidisciplinary team that includes programmers, nurses, pharmacists and physicians brings specific expertise to the project and each member commits at least 25% of his or her time to order set development. Each department has committed clinical champions to help facilitate the development of their order sets, checklists and clinical progressions. For specific order sets such as pacemaker implementation or total hip arthroplasty, it can take only a few weeks from the initial meetings to construct web-based CPOE. Feedback and modification can then be undertaken while the details of design decisions are still fresh in people's minds.

Conclusions

Computerized physician order entry is a disruptive technology requiring extensive participation and buy-in from the clinical community. There was strong sentiment by our health care professionals that they were unwilling to commit significant time and energy into a project that had no immediate tangible benefits. The web-based CPOE project allowed us to avoid problems with legacy systems, such as inflexibility, long lead times, and expense. In addition, web-based CPOE allows utilization of user-interface

designs based on standard browser technology and to have the flexibility of using a variety of input devices.

We have developed a web-based CPOE system that has fulfilled our original specifications and more. It has shown itself to be a robust yet agile development environment. We have the ability to build order sets, nested order sets, pharmacy orders, checklists and care plans. We have the ability to connect to external knowledge-base development tools such as Stanford's protégé and have allowed secure wireless connectivity. While it is too early to make any final judgments the web-based CPOE system has been accepted well by the physicians who have been exposed to it and participation by health care providers in the various departments is excellent.

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